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9 January 1980

USSR Report

SPACE

(FOUO 1/80)

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USSR REPORT

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I. M‹ NED MISSION HIGHLIGHTS

'AIR & COSMOS' COMMENTARY ON CONTINUED MANNING OF SALYUT-6

Paris AIR ET COSMOS in French No 786, 10 Nov 79 p 42

[Article by Pierre Langereux: "New Cosmonauts Are Preparing To Man Salyut-6"]

[Text] Radio Moscow announced at the end of October that the Soviet Salyut-6 orbital station, which has been unoccupied since 19 August 1979, could receive a new crew and that it is currently being checked-out with this in mind [Moscow World Service in English 1300 GMT 29 Oct 79; see JPRS 74805]. But Radio Moscow did not give the precise date for this new mission, which, judging from the past, would involve a crew of two Soviet cosmonauts. Vladimir Shatalov, director of cosmonaut training, had announced to the American press that the USSR will not resume manned flights until next year! According to Shatalov, the USSR will continue the joint Soviet-Intercosmos missions in 1980 with successive flights of the first cosmonauts from Hungary, Cuba, Vietnam, Mongolia and Romania. These joint flights will be launched before mid-1982 when the first French astronaut will be flown on board the Salyut station together with a Soviet cosmonaut.

The USSR Is Preparing a Mission Longer Than 175 Days

Since it was launched on 29 September 1977, the Soviet Salyut-6 orbital station has already been manned by seven crews (two cosmonauts per crew). Throughout these missions, the USSR was able to establish new records in spaceflight endurance of 96, 140 and 175 days, all of which were achieved successively on board Salyut-6.

The deputy director of the Space Research Institute in Moscow, M. Nefedov, told us recently that the next Soviet flights will exceed the 175-day world record just established by Soviet cosmonauts. Nefedov said that the USSR is preparing to undertake a mission longer than 6 months, but he did not indicate whether this mission would take place on board the present Salyut-6 station or on the next station, Salyut-7. The USSR seems to want to increase progressively the length of their manned missions, the limits of which have not yet been defined--if, indeed, there are any.

Man Adapts to Space in One Month

"The first medical examinations of the 175-day mission crew, Vladimir Lyakhov and Valeriy Ryumin, showed that the cosmonauts withstood the prolonged flight well, in any case, not worse than their predecessors" (even though they were totally isolated for the 6 months), Academician Oleg Gazenko, director of the Institute of Biomedical Problems in Moscow, told the FRANCE-USSR REVIEW.

"Spaceflight exerts a certain action on the human organism which modifies its physiological state. These modifications are part of the process of adaptation. At the present time we have no serious reason to look upon this as a major disorder," said Gazenko, who noted that "the process of adapting to weightlessness occurs progressively: it consists of several stages, and the organism's stability is established 1 - 1 1/2 months after launching." Short duration flights are, from this point of view then, a handicap, as the Soviets have confirmed with their Soviet-East European crews: the cosmonauts are generally sick for the first 3 days of flight!

"The fact that we must facilitate the cosmonauts' readaptation and that they have recourse to a variety of prophylactic procedures does not make it possible for us to study the degree, duration and totality of the adaptation to spaceflight. One can only set forth hypotheses based on the results of biological experiments," Oleg Gazenko remarked.

The Average Individual Adapts Best

"Thus," he explains, "we are discovering the physiological changes involved in manned spaceflights as many traits common to all cosmonauts as individual differences. We know well that relatively perfect adaptation to space conditions exposes the subject to the common problems upon his return to earth."

Consequently, one of the main objectives of Soviet biomedical research is to define the level of adaptation to space conditions which would also make it possible to forego some of the more difficult readaptations after the flight. Another, no less important, objective is to determine man's individual ability to adapt in space. "We are studying various means of resolving this problem," said Oleg Gazenko, "because it would be interesting to formulate a theory on biological adaptability and to define man's "adaptation norm."

Ninety-two Earthlings Have Spent 6 Years in Space

Oleg Gazenko thinks that "with time the role of the genotype in man's resistance to extreme environment factors will acquire an ever-increasing importance" and that this question leads to the study of the impact of spaceflight on man's biological evolution. Gazenko believes that "flights limited to a few individuals, no matter what their duration, cannot in any way affect man's biological evolution. But flights of crews representing a rather large population can lead theoretically to a biological evolution that is based on mutations induced by ionizing cosmic radiation." While unforeseen, these mutations are purely random and do not exhibit some kind of definitive "space characteristic." As for weightlessness, if it should have an effect, it will exercise, judging from the past, only a selective influence.

But, notes Gazenko, our conclusions must be prudent because we are still in the initial phase of man's conquest of space. In 18 years, 92 people have been in space and half of them have made at least two flights. The total time in space is approaching 6 years!

[1853/5-P]

II. LIFE SCIENCES

'AIR & COSMOS' COMMENTARY ON SOVIET BIOLOGICAL SATELLITE PROGRAM

Paris AIR ET COSMOS in French No 783, 20 Oct 79 pp 54-55

[Article by Albert Ducrocq: "The Biosputnik Program"]

Text] Since the suspension of the American biological satellite program--more than 10 years ago (Biosat No 3 returned on 7 July 1969 with the monkey Bonnie who was dying on board)--the Russians have been the only ones to use space for biological experiments through their well-known Biosputnik program.

The Soviets use the term Biosputnik to refer to a modified Vostok, which they have converted to carry biological specimens.

We are familiar with the design of the space vehicle, which in 1961 made possible the flight of the first cosmonauts. Yuriy Gagarin's Vostok (4,725 kg) consisted of a service module--essentially comprised of a cylindrical retro-rocket surrounded by [fuel] tanks--forming a single unit with a spherical cabin having a diameter of 2.2 meters. This cabin was very strong and presented the advantage of being able to return at any angle.

People were astonished that the Vostok was not used more. As a matter of fact, although it was used only on six occasions for manned flights in its original configuration, it was widely used for automatic flights; a number of Cosmos reconnaissance vehicles were Vostoks whose cabins had been converted in order to carry cameras.

The automatic Vostok became more specialized. It brought forth Biosputnik 1 with Cosmos 110 which, on 22 February 1966, carried the two dogs Veterok and Ugolek into space; for this flight, the Russians had selected a duration of 22 days, which would practically become the duration for all satellites in this series; this constraint was determined by the orbit and certain physical characteristics of Biosputnik which, moreover, was perfected with a view to its biological role.

Specialists followed its evolution as the Russians launched in succession Biosputnik 2 (Cosmos 368) on 8 October 1970 (in the presence of President Georges Pompidou), Biosputnik 3 (Cosmos 605) on 31 October 1973, and

Biosputnik 4 (Cosmos 690) on 22 October 1974. At that stage, the Intercosmos organization was already involved in the program which would subsequently become largely internationalized. On 26 November 1975, Biosputnik 5 (Cosmos 782) was launched with French, Czechoslovak, and American experiments; the Soviets had installed a g-force generating centrifuge on this Biosputnik 5. By putting specimens of the same kind on this centrifuge and elsewhere in the vehicle, it became possible to draw a dividing line between weightlessness and the other factors of the space environment.

Then Biosputnik 6 (Cosmos 936) was launched into space on 3 August 1977.

Every Two Years

This schedule gives us the pace of operation. The Soviets apparently launch one Biosputnik every 2 years. That is little, one might say. In reality, the bottleneck is not in the operational phase itself but in the preparatory phases. We must realize that setting up biological experiments is always an extremely time-consuming activity. It is, as a matter of fact, a good idea first of all to conduct preliminary research in order to select the specimens wisely and then, after the details of an experiment have been decided, to make sure that one will have these biological specimens at the anticipated date. This is why this date is always set very far in advance and the breeding programs are drawn up accordingly. These programs are rather difficult because, in addition to the flight specimens, it is necessary to have control subjects on the ground, and both of them must be healthy and representative; this means that the selection must be made from a sufficiently large lot, the specimens in question constituting the nth generation of a breed. In practice it is not unusual for several hundreds of subjects to be bred for a dozen to be flown.

A criticism frequently addressed to the biological research programs concerns their disorderly character. For many specialists, biosats are catch-all satellites where everybody wants to put his own experiment without considering that all of the experiments on board the satellite should conform to a precise plan--much less that all of the experiments conducted throughout the entire biosat program should be related.

This is what the situation is now. But does this mean that this criticism is justified? One must realize that biological research is still in its infancy today. We know too little about the cell and the organism to allow ourselves to impose a research plan; it would be very presumptuous to order in advance that one experiment is to be considerably more profitable than another one.

The truth is that the experiments are designed not so much to be part of a plan but rather to benefit from the means offered by a particular species to cast light upon a specific question. In other words, we are now in the speculation stage. Only after that will real programs be drawn up in the light of the knowledge obtained, the moment analysis of the result points to a particular line of research.

One must, however, ask oneself whether specialists today are not just about to discover that line. The contribution of the last biosat as a matter of fact could be decisive if the results measure up to the expectations.

Biosputnik 7

Biosputnik 7 was launched on 25 September under the designation Cosmos 1129. The satellite was recovered on 14 October (see page 50 [of original]). One can say that rarely have scientific results been anticipated with such impatience.

The new Biosputnik--whose structure seems to be the same as that of the two preceding satellites in the series--is in effect important not only by virtue of the number of experiments it is carrying (no less than 13 American experiments, in addition to Soviet, Czechoslovak, and French experiments). Certain of these experiments are quite remarkable, and through them it may be determined that scientists are now beginning to answer questions which they have been asking since the start of the space age.

In particular, it is known that Biosputnik 7 carried one of the American experiments which consisted in modifying the cylinders containing rats so as to permit copulation between a male and a female. The two animals were placed in two contiguous cylinders and the connecting door was opened on the day after orbital insertion.

If there is no copulation, specialists will not fail to look for the reason. And if the female rat is carrying offspring, it will be said that this is of major importance because we will have for the first time the formation and development in space of a mammal embryo during the most critical phase of gestation (the latter lasting something like 35 days in the rat), the period of time when, in the eyes of specialists, the space environment would have the most chance of manifesting itself.

Certain specialists expect to register development anomalies in the light of the Biobloc experiments, which have been pursued thanks to Biosputnik 7.

Artemia Salina

With regards to these Biobloc experiments, there has been much talk since 1972 about artemia salina. It is perhaps not superfluous to recall that this is a real organism since artemia salina is a multicellular organism of the arthropod branch; we must realize of course that the articulated body of this crustacean (having a calcareous chitin instead of a skin) is extended through the members. The name artemia, which is characteristic of the genus, was given to it because of its leafshaped natatory appendix; the adjective "salina" was added to indicate that this is a species that lives in salt marshes.

It is, therefore, a perfected organism which appeared rather late in the history of evolution, during a period of the Tertiary age called Oligocene, going back about 60 million years. Not only does artemia salina have a digestive system, a circulatory system and a respiratory system, but the animal is also capable of orienting itself. Ordinarily, it swims on its back and presents its belly to the light; but it suffices to place a lamp at the bottom of the tank to get the animal to swim on its belly.

This evolved organism has the characteristics of very easily "putting itself on ice," as it were, and it presents us with a whole range of cases from simple biological slowdown all the way to the pure and simple suspension of activity.

It must in any case be emphasized. When officials in charge of space experiments say that they are putting the eggs of artemia salina on a satellite, one must realize that each egg represents not one cell but a collection of several thousands of cells in the process of differentiation which will give rise to baby shrimp with specific shapes, organs, and behavior.

High Relative Biological Effectiveness

During the Biobloc 1 and Biobloc 2 missions--launched, respectively, on board Apollo 16 and Apollo 17--the behavior of the eggs of artemia salina, as we know, turned out to be a total surprise.

It was calculated in effect that these eggs would be subjected to a radiation dose which would only represent a fraction of a rad, a dose very much below the threshold considered dangerous. Thus, the difference could not have been considerable between the specimens left on the ground and the specimens sent out into space. Now, that difference turned out to be enormous. In the specimens that traveled in the Apollo rockets, there was something of a slaughter, as we know: about 10 percent of the eggs were "killed" by cosmic radiation and, besides, a large number of victims was discovered among the eggs that were not touched directly but that were hit by secondary radiation.

Such consideration seemed to justify that the parameter to take into consideration in estimating the biological harmfulness of radiation--even more so than the radiation dose--would have to be the RBE, or the "relative biological effectiveness," since that parameter in some way measures the coefficient of damage amplification when radiation consists of a rain of atomic nuclei. Traditionally, biologists believe that the RBE would exceed 10 in the case of fast protons--we realize, of course, that the quantity of fast protons physically exerting the effects of a radiation of 1 rad would biologically have the effectiveness of a radiation of 10 rads--and that the RBE could attain a figure of several score if we assume that we have heavy nuclei involved.

The Biobloc 1 and Biobloc 2 experiments taught us that these coefficients had not been overestimated. According to certain specialists, the RBE, in certain cases, might even assume values on the order of 100 or more.

This is in accordance with the assumption that the destruction of eggs recorded in the first Biobloc experiments was actually caused by cosmic radiation--something which is not at all certain in view of the handling requirements. Biologists were in effect forced to immobilize the eggs by inserting them into plastic matter which gave them a particularly unfavorable environment and this fixation may have made those samples fragile.

Drawing the Dividing Line

It is necessary for this reason to pursue the program and to establish new formulas which would make it possible to accomplish the proper separation.

Naturally, the Biobloc operations are on the list of experiments which the French suggested to the Soviets and which the latter accepted.

One Biobloc 3 was completed by the GRBS (Space Biology Research Group) at Toulouse and was entrusted to the Russians. The idea was to ask the cosmonauts to secure this Biobloc on the outside wall of a Salyut station during an EVA so that it would have been totally exposed to the space environment. But this experiment could not take place. A Biobloc 4 was thus prepared for Biosputnik 7.

Biobloc 4 was characterized by two innovations:

1.) Recourse to a flexible set of screens to attenuate the action of cosmic rays in a section of the apparatus. Thus, Biobloc 4 was comprised of a section of almost total exposure to space conditions, a section with semi-protection, and a section with extensive protection. The idea obviously was to find out whether we would register, compared to the earlier Biobloc experiments, a reduction in lesions reflecting the protection which the eggs got during the flight.

2.) The placement of tobacco grains in the rocket, along with these artemia salina eggs so that one might compare the effects of cosmic radiation on two very different biological specimens.

The specialists believe that, in light of the results obtained with Biobloc 4, it should be possible at last to delineate very precisely the effect of the heavy nuclei of cosmic radiation upon artemia salina whereas the American experiment will have viewed the problem in a different light. That would certainly be a decisive contribution to the understanding of the role of radiation the effects of which seem to be very different from what we had imagined several years ago; that is to say, under normal circumstances, the effects are evidently less than we had thought, whereas under critical circumstances, they would be much greater.

[1853/1-5058]

UDC: 613.693

PROBLEMS OF SPACE BIOLOGY, VOL 38: PHYSIOLOGICAL AND HYGIENIC ASPECTS OF THE EFFECTS OF HIGH AND LOW TEMPERATURES

Moscow PROBLEMY KOSMICHESKOY BIOLOGII (Problems of Space Biology), Vol 38 "Fiziologo-gigiyenicheskiye aspekty deystviya vysokikh i nizkikh temperatur" (Physiological and Hygienic Aspects of High and Low Temperatures) in Russian 1979 signed to press 18 May 79 pp 4, 261

[Annotation and table of contents from book by Aleksandr Nikolayevich Azhayev, Izdatel'stvo Nauka, 1100 copies, 264 pages]

[Text] This monograph deals with the effects of high and low temperatures on animals and man. The author discusses the effects of convection, radiation and conduction heat and cold on heat and fluid-electrolyte metabolism, the cardiovascular and respiratory systems. Considerable space is devoted in this book to physiological and hygienic substantiation of personal protection against high and low temperatures. New views are voiced on methods of studying heat content of the body and classification of thermal states of man, as well as principles involved in designing heat-regulating systems.

This book is intended for specialists in space biology and medicine.

There are 61 tables and 57 illustrations; bibliography is listed on 37 pages.

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III. SPACE ENGINEERING

UDC 522.1:523.14

STABILIZING LARGE SPACE STRUCTURES

Moscow KOSMICHESKIYE ISSLEDOVANIYA in Russian Vol 17 Issue 4, 1979 pp 547-558

[Article by V. I. Buyakas, "Stabilizing the Shape of an Extendable Surface"]

[Text] The problem of stabilizing the shape of an RF-reflective surface of a large space radiotelescope is analyzed.

The use of a sectional spherical mirror in the construction of an indefinitely extendable space antenna was proposed (Ref. 1). Operational ability would be maintained during each intermediate phase of extension by using large, single-type hexagonal modules on which the RF-reflective panels would be located. The required shape for the RF-reflective surface would be maintained by two systems of automated control. The first of these would control the attitude of the panels relative to the frames of the modules. The present work is devoted to studying the second system, which would control the attitude of the modules relative to each other. It is this system that will be referred to below as the automatic surface shape control system.

The automatic surface shape control system, which includes measuring devices for monitoring the position of three reference points on each module as well as the actuating mechanisms and the system to be regulated, has to provide for stabilizing the reference points on the prescribed surface. Our task consists of choosing (1) the system to be regulated and (2) the control laws that will assure asymptotic stability of the closed system.

General Requirements for the System To Be Regulated

The problem of defining the system to be regulated consists of choosing links between modules that will impart the following properties to the structure.

1. Some of the links have to be maneuverable and equipped with actuating mechanisms for changing the relative position of the modules.

2. Assembly of the structure and translation of modules from one position to another by using actuating mechanisms must not lead to additional (steady state) elastic strains in the modules.

3. For a fixed state of the maneuverable links, the structure must behave like a rigid body (must have six degrees of freedom), with modules and links considered rigid bodies.

4. As the structure has to allow for indefinite extension, the attachment of a new module should entail minimum rebuilding in links constructed earlier. For the structure proposed below, the addition of a single element is accompanied by the rebuilding of links between, at most, 2 or 3 modules to which the module to be attached is fastened.

5. The system to be regulated must be maneuverable. Let the three reference points of some module be fixed by external forces in the required attitude on the surface of stabilization. Then, for arbitrarily small errors in manufacture and assembly, residual strains, and so forth, an arrangement of controllable links must exist so that all remaining reference points lie on the surface of stabilization.

It is not obvious, a priori, that such an arrangement of modules is possible.

Structural Properties

Let n be the number of modules in the structure, p the number of maneuverable links, r the number of nonmaneuverable links, and g = 3n the number of reference points. Then, in order to satisfy the enumerated requirements, it is necessary to satisfy the following conditions:

$$p + r = 6(n - 1) \tag{1}$$

$$p \geq g - 3 = 3(n - 1) \tag{2}$$

$$r \leq 3(n - 1). \tag{3}$$

Proof

Let us introduce a Cartesian system of coordinates and let vector

$$x^{i,s} = (x_1^{i,s}, x_2^{i,s}, x_3^{i,s}), \quad i=1,2,\ldots,n; \quad s=1,2,3,$$

determine the location of the s-th reference point in the i-th module, and let the vector

$$X = (x^{1,1}, x^{1,2}, x^{1,3}, \ldots, x^{i,s}, \ldots, x^{n,1}, x^{n,2}, x^{n,3}) = (x_1^{1,1}, x_2^{1,1}, x_3^{1,1}, \ldots, x_3^{n,3}) -$$

determine the location of all reference points of the structure.

The requirement that the reference points belong to modules places restrictions on the vector X, which we will call internal links:

$$f_1(X) = b_1, \tag{4}$$

where

$$f_1=(f_1^{1,1},\ldots,f_1^{i,s},\ldots,f_1^{n,3}),\quad b_1=(b_1^{1,1},\ldots,b_1^{i,s},\ldots,b_1^{n,3}),\quad s=1,2,3;\quad i=1,2,\ldots,n,$$

$$f_1^{i,1}=\|x^{i,1}-x^{i,2}\|,\ f_1^{i,2}=\|x^{i,2}-x^{i,3}\|,\ f_1^{i,3}=\|x^{i,3}-x^{i,1}\|,\ b_1^{i,s}>0. \tag{5}$$

Also, modules are connected among themselves by external nonmaneuverable and maneuverable links

$$f_2(X) = b_2, \tag{6}$$

$$f_3(X) = b_3. \tag{7}$$

Here f_2 and b_2 are r vectors and f_3 and b_3 are p vectors. For maneuverable links (Equation 7), the value of the link parameter b_3 can be changed by actuating mechanisms. An example of a maneuverable link is a rod, whose length can be regulated, connecting two modules.

Let the length of the maneuverable links be fixed. In order for the structure to behave like a rigid body in this case nd not to be statically overdetermined, it is necessary (Ref. 2) to satisfy the condition

$$p + r = 6(n - 1).$$

We will show that

$$p \geq 3(n - 1).$$

If we assume that $p < 3(n - 1)$, then it follows from Equation 1 that

$$r > 3(n - 1). \tag{8}$$

Let us assume that three reference points of some module, for example, the first one, have been fixed on the stabilization surface and that its internal links are not being disturbed. We will now consider such disturbances of the remaining nonmaneuverable links, which can be written in the form

$$f_{1,2}(X) = b_{1,2} + \delta b_{1,2}, \tag{9}$$

where

$$f_{1,2}=(\bar f_1,f_2),\ \bar f_1=(f_1^{2,1},f_1^{2,2},f_1^{2,3},\ldots,f_1^{i,s},\ldots,f_1^{n,3}),$$

$$b_{1,2}=(\bar b_1,b_2),\ \bar b_1=(b_1^{2,1},\ldots,b_1^{i,s},\ldots,b_1^{n,3}).$$

The equations for the disturbed links (Equation 9) include errors in producing the rods, misalignment of joints, displacement of reference points on the module surface, and sc forth. We will limit ourselves to small disturbances, for which $\delta b_{1,2}$ is an arbitrarily small $(r + 3(n - 1))$ vector.

Let us assume that the maneuverable links are freed and that, in the state $X = X(*)$, the remaining $3(n - 1)$ reference points of the disturbed system (Equation 9) lie on the stabilization surface, given by $\phi(x) = 0$. For each reference point in the neighborhood of the state being considered, let

$$\varphi(x^{i,s})=0;\ i=2,\ldots,n;\ s=1, 2, 3$$

be solvable for one of the variables. Let us designate the set of these variables, which form the $3(n - 1)$ vector, by X_1. By X_2 we will mean a $6(n - 1)$ vector formed by the remaining components of the vector X, $X(*) = (X_1(*), X_2(*))$. Then

$$X_1 = \Phi^{-1}(X_2). \tag{10}$$

We will assume that the functions Φ^{-1} and $f_{1,2}$ are continuous and of class C_1. Substituting Equation 10 in Equation 9, we get the image

$$R^{6(n - 1)} \to R^{r + 3(n - 1)}$$

of class C_1:

$$f_{1,2}(\Phi^{-1}(X_2), X_2)= b_{12} + \delta b_{12}. \tag{11}$$

In order to satisfy requirement 5, it is necessary that for an arbitrarily small δb_{12} in $R^{6(n - 1)}$ in the neighborhood $X_2 = X_2(*)$ there exist an inverse image, which is assured only in the case (Ref. 3) when

$$6(n - 1) \geq r + 3(n - 1).$$

From this we get

$$3(n - 1) \geq r,$$

which contradicts Equation 8. Therefore,

$$p \geq 3(n - 1).$$

We will consider systems with a minimum number of maneuverable links.

For this, it follows from Equations 1 and 2 that

$$p = 3n - 3 \tag{12}$$

$$r = 3n - 3. \tag{13}$$

Let us assume that each maneuverable link is equipped with an actuating mechanism that regulates the shape of the surface, and the structure also contains six actuating mechanisms that regulate the translation and orientation of the structure as a whole. Then the total number of actuating mechanisms in the system is given by

$$m = p + 6 = 3n + 3. \tag{14}$$

Choice of Systems To Be Regulated

The conditions of Equations 12 and 13 are satisfied by the structure shown in Figure 1, where the nonmaneuverable links are formed by rods of fixed length which are connected to the modules by universal spherical joints while the maneuverable links are formed by rods whose length can be changed by the actuating mechanisms. If the modules do not lie in a single plane, the structure allows a change in relative position of the modules, i. e., regulating the position of the reference points. Let us note that the links among all modules, other than the ones on the edge, are the same type.

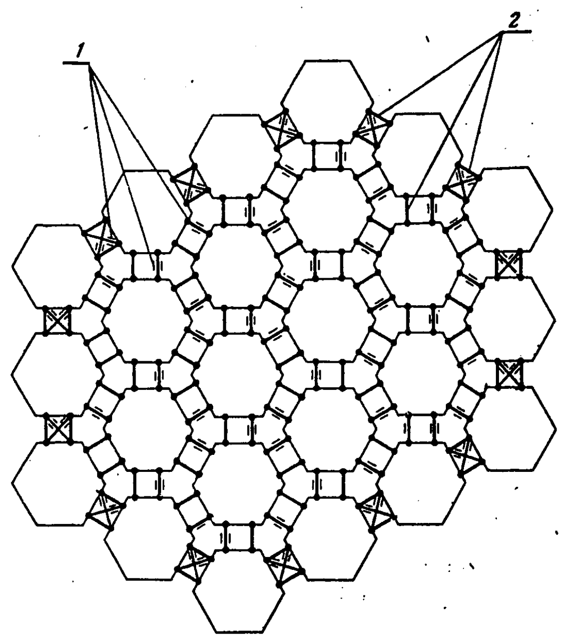

Figure 1. Structure That Is Controlled by Varying the Length of the Tie Rods

Key:

1. Maneuverable links
2. Nonmaneuverable links

It can easily be proved that the structure allows indefinite extension while satisfying the conditions of Equations 12 and 13 at each step. During the addition of a current module, an attendant rebuilding occurs of links between the (adjacent) modules to which the new element is connected.

A second structure, which satisfies conditions of Equations 12 and 13 and which we will consider below, can be obtained by extending according to the following rule:

1. The initial structure consists of three interconnected modules, as shown in Figure 2;

2. Each newly connected element is attached to 2 or 3 modules previously included in the structure with a rebuilding of links between them (Figure 3);

3. In order to simplify the study, structures with partial coverage (Figure 4) will be excluded from consideration.

Modules are connected by rods that are fastened to them by joints of one of three types (Figure 3): (1) Cylindrical joints whose axes of rotation are orthogonal to the plane of the module, (2) Cylindrical joints whose axes of rotation are parallel to the edge of the module, and (3) Universal spherical joints; points 1, 2, and 3 on each module are the reference points.

An actuating mechanism is associated with each type 1 joint, which makes it possible to change the angle between the axis of the joint and the tie rod. The actuating mechanism for type 2 joints (such joints occur only along the edge in Figure 3) makes it possible to place the tie rods in torsion. Type 3 spherical joints are not controlled. A possible method for implementing a controlled link using a type 1 joint is shown in Figure 5. Here actuating mechanism IV changes the length of the rod joining points I and II.

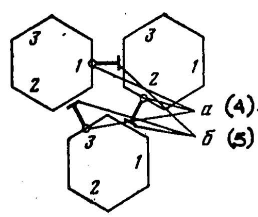

Figure 2. Initial Structure

Key:

1, 2, 3. Reference points
4. Cylindrical joints with axes of rotation orthogonal to the plane of a module
5. Cylindrical joints with axes of rotation parallel to the edge of a module

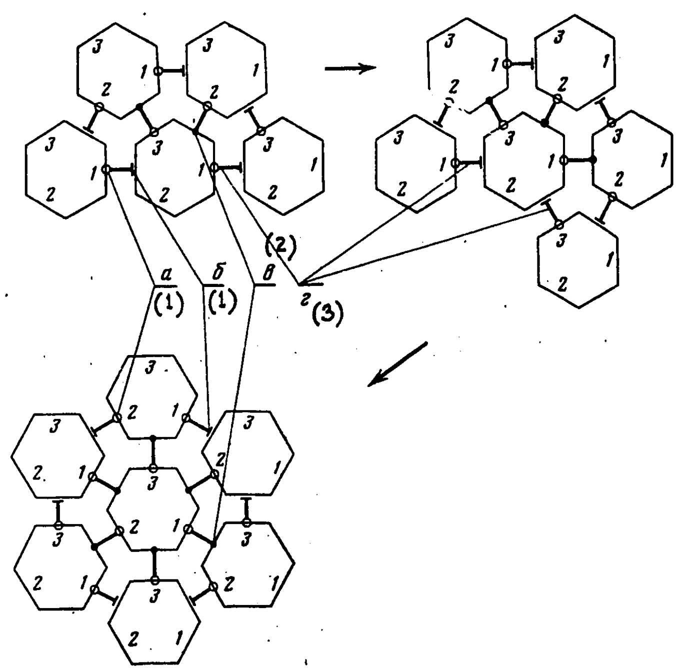

Figure 3. Extension of the Structure

Key:

1. Cylindrical joints
2. Spherical joints
3. Links that are changed during extension

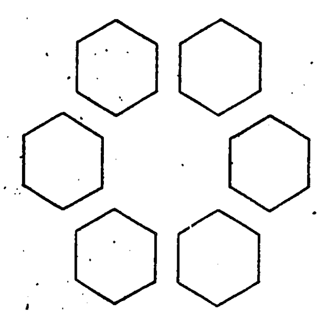

Figure 4. Structure With Partial Coverage

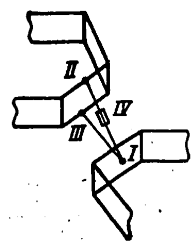

Figure 5. Possible Technique for Achieving Maneuverable Linkage. Spherical joints are located at points I, II, and III. The actuating mechan-mechanism is located at point IV

In this fashion, all links other than the ones on the edge are of the same type. In making extensions, the links between 2 or 3 modules that become internal ones have to be rebuilt.

Conditions that are stated as Equations 12 and 13 and are satisfied in the structure being considered only represent the necessary conditions for satisfying the requirements enumerated above. We will further limit ourselves to the case where the stabilization surface is a plane and we will show that the requirements are indeed satisfied. If we take for granted the properties to be proved below, these requirements are also satisfied by any surface close to a plane and, in particular, by spheres of sufficiently large diameter.

System With Fixed Maneuverable Links

We will show that for fixed maneuverable links, the structure behaves like a rigid body (it has six degrees of freedom), if modules and rods are considered rigid and joints are considered ideal.

Let us consider the link equations (both internal and external) for a fixed position of one of the modules, for example, of the first one:

$$f(X)=b;\ x^{1,s}=\text{const};\ s=1,\ 2,\ 3, \tag{15}$$

where $f = (f_1, f_2, f_3)$, $b = \overline{b}_1, b_2, b_3$, $\dim f = 3 \cdot 3(n - 1)$ and the system

$$\left.\frac{\partial f}{\partial X}\right|_{x=x(\circ)} dX=0;\quad dx^{1,s}=0,\ s=1,2,3. \tag{16}$$

It is sufficient to show that the system of Equation 16 has only a trivial solution for dX, in which case the rank of the matrix of coefficients of the system (Equation 16) equals 9n

$$\operatorname{rank}\left|\frac{\partial f}{\partial X}\right|_{X=X(*)}=3\cdot 3\cdot(n-1). \tag{17}$$

In the neighborhood of the state X = X(*), the system of Equation 15 can be solved for X as follows,

$$X = X(b),$$

and the position of the structure is uniquely determined by the position of the fixed module, i. e., the system behaves like a rigid body.

This also makes possible regulation without elastic deformations (requirement 2), because for an arbitrary value of the link parameters (vector b) in the neighborhood of X = X(*), the link equations uniquely determine the relative positions of the modules.

Equations 15 and 16 are cumbersome. Relative displacement of the modules is more conveniently described by the rotation angles of the joints. Let us introduce the vector A into our consideration, whose coordinates are the angles of the joints of the structure; its dimension depends on the number of modules. To each cylindrical joint, there corresponds one coordinate α_i of vector A; to each spherical joint there correspond three coordinates. Since the structure consists of kinematically closed loops, relationships exist among the coordinates of vector A. In fixing the position of one of the modules, the vector dA uniquely determines the vector dX, and it is only necessary to show that dA ≡ 0 for an arbitrary number of modules.

The proof will be carried out by using induction, for a system of three modules initially and then for an arbitrary number of modules.

Let us consider a structure consisting of three modules (Figure 6). We

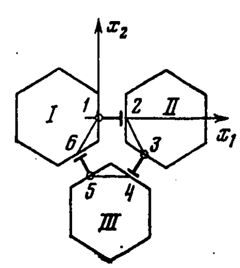

Figure 6. Structure Consisting of Three Modules. The x_3 axis is orthogonal to the plane of the first module

introduce a Cartesian system of coordinates with its origin at the first module. Let vector x^i determine the position of the i-th point and the vector ω^i the direction of the axis of the i-th joint, $r^{s,k} = (x^s - x^k)$, and α^i the angle of the i-th joint. Then

$$dx^3=[\omega^1,\ r^{3,1}]d\alpha^1+[\omega^2,\ r^{3,2}]d\alpha^2, \tag{18}$$

$$d\omega^3=[\omega^1,\ \omega^3]d\alpha^1+[\omega^2,\ \omega^3]d\alpha^2, \tag{19}$$

$$dx^3=[\omega^4,\ r^{3,4}]d\alpha^4+[\omega^5,\ r^{3,5}]d\alpha^5+[\omega^6,\ r^{3,6}]d\alpha^6, \tag{20}$$

$$d\omega^3=[\omega^4,\ \omega^3]d\alpha^4+[\omega^5,\ \omega^3]d\alpha^5+[\omega^6,\ \omega^3]d\alpha^6. \tag{21}$$

At the cylindrical joint at location 3, the expressions for dx^3 and $d\omega^3$ have to coincide. After appropriate calculations and combining Equations 18 through 21, we find

$$\begin{gathered}\frac{\sqrt{3}}{2}l_2\,d\alpha^1=-\frac{\sqrt{3}}{2}l_1\,d\alpha^5,\quad \left(l_1+\frac{1}{2}l_2\right)d\alpha^1=\left(l_2+\frac{1}{2}l_1\right)d\alpha^6,\\ -\frac{1}{2}l_2\,d\alpha^2=l_1\,d\alpha^4+\frac{1}{2}(l_1+l_2)\,d\alpha^6,\quad d\alpha^5=-\frac{1}{2}d\alpha^4-\frac{1}{2}d\alpha^6,\\ 0=-\frac{\sqrt{3}}{2}d\alpha^4+\frac{\sqrt{3}}{2}d\alpha^6,\end{gathered} \tag{22}$$

where l_2 is the length of the module edge, l_1 is the length of the tie rod. For the condition $l_1 \neq 0$, $l_2 \neq 0$, the system of Equation 22 has only a trivial solution, and from Equations 15 and 15 it follows that for $n = 3$, the structure behaves like a rigid body.

Let a system consisting of n modules behave like a rigid body. We will show that a structure consisting of (n + 1) elements has the same property. Two types of extension are possible: The new element is joined either to 2 or to 3 elements previously included in the structure.

For the first case the (n + 1)-th module is attached to the (n - 1)-th and to the n-th modules (Figure 7). The process of extension is accompanied by the replacement of the cylindrical joint at point 2 by a spherical one, which is equivalent to introducing at this location two additional cylindrical joints whose axes $\omega^{2'}$ and $\omega^{2''}$ are along axes x_1 and x_3 in accordance with Reference 4, and the addition of new links between (n + 1)-th module and the (n - 1)-th and n-th modules.

If α^i is the angle that determines the attitude of the i-th joint and $\alpha^{2'}$ and $\alpha^{2''}$ are the angles in the joints whose axes are along $\omega^{2'}$ and $\omega^{2''}$, then the effect of the structure on the (n - 1)-th and n-th modules is such that

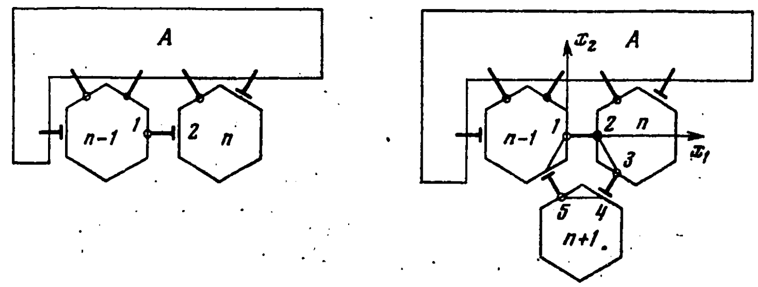

Figure 7. Extending the Structure. The x_3 axis is orthogonal to the plane of the (n - 1)-th module. A is the remaining part of the structure

$$d\alpha^1 = 0,\ d\alpha^2 = 0.$$

Then, in a system consisting of (n + 1) modules, the change in angles $\alpha^{2'}$ and $\alpha^{2''}$ will lead to a change in vectors x^3 and ω^3 such that

$$\begin{aligned} dx^3 &= [\omega^{2'}, r^{3,2}]d\alpha^{2'} + [\omega^{2''}, r^{3,2}]d\alpha^{2''}, \\ d\omega^3 &= [\omega^{2'}, \omega^3]d\alpha^{2'} + [\omega^{2''}, \omega^3]d\alpha^{2''}. \end{aligned} \tag{23}$$

On the other hand

$$\begin{aligned} dx^3 &= [\omega^4, r^{3,4}]d\alpha^4 + [\omega^5, r^{3,5}]d\alpha^5 + [\omega^6, r^{3,6}]d\alpha^6, \\ d\omega^3 &= [\omega^4, \omega^3]d\alpha^4 + [\omega^5, \omega^3]d\alpha^5 + [\omega^6, \omega^3]d\alpha^6. \end{aligned} \tag{24}$$

By equating Equations 23 and 24, we obtain the following system

$$\frac{\sqrt{3}}{2} l_2\, d\alpha^{2''} = -\frac{\sqrt{3}}{2} l_1\, d\alpha^5, \quad \frac{1}{2} l_2\, d\alpha^{2''} = \left(l_2 + \frac{1}{2} l_1\right) d\alpha^5,$$

$$-\frac{\sqrt{3}}{2} l_2\, d\alpha^{2'} = l_1\, d\alpha^4 + \frac{1}{2}(l_1 + l_2)\, d\alpha^6, \quad 0 = -\frac{1}{2} d\alpha^4 - \frac{1}{2} d\alpha^6,$$

$$d\alpha^{2'} = -\frac{\sqrt{3}}{2} d\alpha^4 + \frac{\sqrt{3}}{2} d\alpha^6.$$

We can easily convince ourselves that when $l_1 \neq 4l_2$, the system has only a trivial solution. Therefore, if this condition is satisfied, then the (n - 1)-th, n-th, and (n + 1)-th modules are rigidly connected among themselves. But if $d\alpha^{2'} = d\alpha^{2''}$, then according to the assumption, the structure of n modules is a rigid body, i. e., the (n - 1)-th and the n-th modules are immobile with respect to the rest of the structure and, therefore, the entire system of (n + 1) elements will behave like a rigid body.

It can be shown analogously that joining the (n + 1)-th module to three modules previously included in the structure yields a system that behaves like a rigid body.

Maneuverability of the Structure

The system has to be designed in such a fashion that for arbitrarily small disturbances in the links brought on by errors in manufacture and assembly, strain, and so forth, there exists such an arrangement of maneuverable links that all reference points will lie on the surface of stabilization (requirement 5). A system that has this property will be called a maneuverable system. We will show that the structure considered, when its surface of stabilization is a plane, forms a maneuverable system.

It was shown earlier with the attitude of one of the modules given and with maneuverable links fixed, the state of the structure is uniquely determined, i. e.,

$$\rho = \rho(\beta), \tag{25}$$

where the coordinate ρ of the vector $\rho = (\rho_1, \ldots, \rho_i, \ldots \rho_{3n-3})$ determines the displacement along the normal direction of the i-th reference point from the stabilization surface, and the coordinate β_i of the vector $\beta = (\beta_1, \ldots, \beta_i, \ldots, \beta_{3n-3})$ determines the position of the i-th maneuverable link.

Equation 25 describes the displacement of the reference points when all nonmaneuverable elements of the structure have been manufactured precisely. For disturbances of links, which were considered small, random, and known, Equation 25 takes the form

$$\bar{\rho} = \bar{\rho}(\beta).$$

Let the functions $\rho(\beta)$ and $\bar{\rho}(\beta)$ be continuous and

$$\operatorname{rank}\left|\frac{\partial\rho}{\partial\beta}\right|_{\beta=\beta(*)} = 3(n-1). \tag{26}$$

Here $\beta = \beta(*)$, that is, the value of the maneuvered links for which $\rho = 0$. Then, taking the condition in Equation 26 for granted, for sufficiently small disturbances of the links

$$\operatorname{rank}\left|\frac{\partial\bar{\rho}}{\partial\beta}\right|_{\beta=\beta(*)} = 3(n-1)$$

there exists in the neighborhood of $\beta = \beta(*)$ a reciprocally single-valued correspondence between $\bar{\rho}$ and β for which $\bar{\rho} = 0$.

Thus, Equation 26 is a sufficient condition for maneuverability. We will now consider the case when the stabilization surface is a plane. Let us introduce a Cartesian system of coordinates and arrange the structure in the plane $x_3 = 0$, as shown in Figure 8. Points labeled 1, 2, and 3 in the

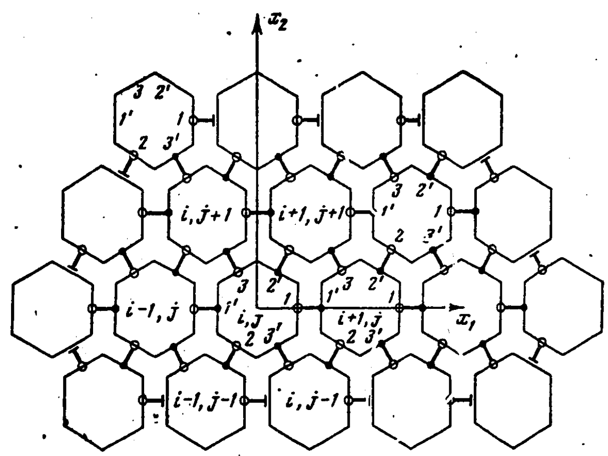

Figure 8.

modules are the reference points. The condition of Equation 26 in the case being considered here has the form

$$\operatorname{rank}\left|\frac{\partial y}{\partial \beta}\right|_{\beta=\beta(\cdot)} = 3(n-1), \tag{27}$$

where the coordinates of vector y are ordered by the three indices

$$y_{i,j,s} = x_3^{i,j,s}, \quad s = 1,2,3.$$

The controllable links of the structure have the following form. In joints of type 1 (cylindrical joints arranged orthogonally to the surface of the module)

$$\begin{aligned}
(n^{i,j}, (x^{i+1,j,1'} - x^{i,j,1})) &= l_1 \cos\beta^{i,j,1},\\
(n^{i,j}, (x^{i-1,j-1,2'} - x^{i,j,2})) &= l_1 \cos\beta^{i,j,2},\\
(n^{i,j}, (x^{i,j+1,3'} - x^{i,j,3})) &= l_1 \cos\beta^{i,j,3}.
\end{aligned} \tag{28}$$

Here $\beta^{i,j,s}$ (s = 1, 2, 3) are controlled angles, $n^{i,j}$ is the unit vector of the normal to the i,j-th module, which is written as:

$$n^{i,j}=\frac{1}{S}\left[\left(x^{i,j,3}-x^{i,j,1}\right),\ \left(x^{i,j,2}-x^{i,j,1}\right)\right],$$

where

$$S=\frac{3\sqrt{3}}{2}l_2^2.$$

The equations for the maneuverable links located along the edge in type 2 joints (twisting) have the form

$$\begin{gathered}
\left(n^{i-1,j},\ \left(x^{i,j,3}-x^{i,j,2}\right)\right)=\sqrt{3}l_2\cos\beta^{i,j,1'},\\
\left(n^{i+1,j+1},\ \left(x^{i,j,1}-x^{i,j,3}\right)\right)=\sqrt{3}l_2\cos\beta^{i,j,2'},\\
\left(n^{i,j+1},\ \left(x^{i,j,2}-x^{i,j,1}\right)\right)=\sqrt{3}l_2\cos\beta^{i,j,3'}.
\end{gathered}\tag{29}$$

For infinitesimally small changes $d\beta$ in the controlled angles, there arise infinitesimally small displacements dx of the reference points. If we limit ourselves to considering displacements in the neighborhood of the state $\beta = \beta(*)$ when all reference points lie on the surface $x_3 = 0$, then, from Equations 28 and 29 and by making appropriate computations, we obtain

$$\begin{gathered}
\frac{1}{l_1}\left(k\left(2dx_3^{i,j,1}-dx_3^{i,j,2}-dx_3^{i,j,3}\right)+\left(dx_3^{i,j,1}-dx_3^{i+1,j,1'}\right)\right)=d\beta^{i,j,1},\\
\frac{1}{l_1}\left(k\left(2dx_3^{i,j,2}-dx_3^{i,j,3}-dx_3^{i,j,1}\right)+\left(dx_3^{i,j,2}-dx_3^{i-1,j-1,2'}\right)\right)=d\beta^{i,j,2},\\
\frac{1}{l_1}\left(k\left(2dx_3^{i,j,3}-dx_3^{i,j,1}-dx_3^{i,j,2}\right)+\left(dx_3^{i,j,3}-dx_3^{i,j+1,3'}\right)\right)=d\beta^{i,j,3},\\
\frac{1}{\sqrt{3}l_2}\left(\left(dx_3^{i,j,2}-dx_3^{i,j,3}\right)-\left(dx_3^{i-1,j,2}-dx_3^{i-1,j,3}\right)\right)=d\beta^{i,j,1'},\\
\frac{1}{\sqrt{3}l^2}\left(\left(dx_3^{i,j,3}-dx_3^{i,j,1}\right)-\left(dx_3^{i+1,j+1,3}-dx_3^{i+1,j+1,1}\right)\right)=d\beta^{i,j,2'},\\
\frac{1}{\sqrt{3}l_2}\left(\left(dx_3^{i,j,1}-dx_3^{i,j,2}\right)-\left(dx_3^{i,j-1,1}-dx_3^{i,j-1,2}\right)\right)=d\beta^{i,j,3'},
\end{gathered}\tag{30}$$

where

$$\begin{gathered}
dx_3^{i,j,1'}=\frac{2}{3}\left(dx_3^{i,j,2}+dx_3^{i,j,3}\right)-\frac{1}{3}dx_3^{i,j,1},\\
dx_3^{i,j,2'}=\frac{2}{3}\left(dx_3^{i,j,3}+dx_3^{i,j,1}\right)-\frac{1}{3}dx_3^{i,j,2}.\\
dx_3^{i,j,3'}=\frac{2}{3}\left(dx_3^{i,j,2}+dx_3^{i,j,1}\right)-\frac{1}{3}dx_3^{i,j,3},
\end{gathered}$$

If the position of one of the modules, for example, the m,t-th one is fixed, then it is necessary to assume the following in the system of Equations 30:

$$dx_3^{m,t,s} = 0;\ x = 1,\ 2,\ 3.$$

The coefficients of the system of Equation 30 then form the matrix

$$\left|\frac{\partial y}{\partial \beta}\right|_{\beta=\beta(\bullet)}$$

and it is necessary to prove Equation 27 for an arbitrary n.

In the section, System With Fixed Maneuverable Links, it was shown that in the system of Equations 16

$$\operatorname{rank}\left|\frac{\partial f}{\partial X}\right|_{X=X(\bullet)} = 3\cdot 3(n-1).$$

We can check that Equations 30 form a subsystem of the system of Equation 16 if we set $d\beta = 0$ and assume that the m,t-th module is the first one. Since the total number of equations in the system of Equations 16 equals 9n, then the conditions of Equation 17 are satisfied only when the rank of the matrix of coefficients for an arbitrarily selected subsystem consisting of p equations equals p. Therefore, the rank of the matrix of coefficients for the subsystem of Equation 30 equals 3(n - 1), the conditions of Equation 27 are satisfied, and the system is controllable.

Choosing Control Laws To Assure Asymptotic Stability of the Closed System

It was shown above that, as designed, the system to be regulated is maneuverable and all reference points lie on the stabilized surface (for surfaces close to a plane). For the case of arbitrarily small deviations of the reference points from the required position there exists for the controllable links a state for which the control error becomes zero. It might turn out that this produces a simple means of regulation: To measure the deviation of the control points, then to compute the necessary attitude and have the control system execute the commands.

However, such a method of control is not possible. The translations of the reference points are controlled with great precision, whereas displacements of links are either not measured at all or are measured with substantially lower precision. For this reason, the calculation of the necessary displacement of maneuverable links as a function of regulation error can be realized only for an ideal model (link equations without accounting for strain and inaccuracies of manufacture and assembly), and not for real structures. Fixing maneuverable links in the calculation situation does not remove the error of regulation. In connection with this, an iterative regulation procedure is proposed.

Let us consider the equation

$$f(\rho) = \phi(\beta), \tag{31}$$

which defines the displacement along the normal ρ of the reference points from the stabilization surface when the position of one of the modules on this surface is fixed and the position β of the maneuvered link is given. We will designate by $\beta(q)$ the state of the maneuverable links during the q-th cycle and by $\rho(q)$ the corresponding displacement of the reference points. The equation for the linear approximation for the system of Equation 31 has the form

$$B\rho(q) = \frac{\partial f}{\partial \rho}\bigg|_{\rho=0} \rho(q) = \frac{\partial \varphi}{\partial \varphi}\bigg|_{\beta=\beta(*)} \delta\beta(q) = \frac{\partial \varphi}{\partial \beta}\bigg|_{\beta=\beta(*)} \times(\beta(q)-\beta(*)) = C\delta\beta(q).$$

Let the matrix B be nonsingular and the selected linear control law

$$\delta\beta(q) = D\rho(q-1) \tag{32}$$

then

$$\rho(q) = B^{-1}CD\rho(q-1). \tag{33}$$

It is known (Ref. 5) that the system of Equation 31 with the controllers of Equation 32 is asymptotically stable (locally) with respect to the equilibrium state, if the system of Equation 33 is asymptotically stable, and the problem of stabilization consists of choosing a matrix D in such a fashion that the eigenvalue of the matrix $B^{-1}CD$ satisfies the condition

$$|\lambda| < 1.$$

We will indicate one class of control laws that insure asymptotic stability for the system considered in the neighborhood of a plane.

Let B be the nonsingular matrix and assume that such a choice of matrix D is possible so that

$$B = K'CD.$$

Then, from Equation 33, it follows that

$$\rho(q) = K'\rho(q-1), \tag{34}$$

and for $|K'| < 1$ the asymptotic stability of the system is assured.

It was shown earlier that for the case being considered the matrix B is nonsingular and $\partial\phi/\partial\beta$ is diagonal in form. Then it follows from Equation 30 that by choosing the following control laws

$$\delta\beta^{i,j,1}(q+1)=k'\frac{1}{l_1}(k(2\rho_{i,j,1}(q)-\rho_{i,j,2}(q)-\rho_{i,j,3}(q))+$$
$$+(\rho_{i,j,1}(q)-\rho_{i+1,j,1'}(q))),$$
$$\delta\beta^{i,j,2}(q+1)=k'\frac{1}{l_1}(k(2\rho_{i,j,2}(q)-\rho_{i,j,3}(q)-\rho_{i,j,1}(q)+$$
$$+(\rho_{i,j,2}(q)-\rho_{i-1,j,2'}(q))),$$
$$\delta\beta^{i,j,3}(q+1)=k'\frac{1}{l_1}(k(2\rho_{i,j,3}(q)-\rho_{i,j,1}(q)-\rho_{i,j,2}(q))+$$
$$+(\rho_{i,j,3}(q)-\rho_{i,j+1,3'}(q))),$$
$$\delta\beta^{i,j,1'}(q+1)=k'\frac{1}{l_2\sqrt{3}}((\rho_{i,j,2}(q)-\rho_{i,j,3}(q))-(\rho_{i-1,j,2}(q)-\rho_{i-1,j,3}(q))).$$
$$\delta\beta^{i,j,2'}(q+1)=k'\frac{1}{l_2\sqrt{3}}((\rho_{i,j,3}(q)-\rho_{i,j,1}(q))-$$
$$-(\rho_{i+1,j+1,3}(q)-\rho_{i+1,j+1,1}(q))),$$
$$\delta\beta^{i,j,3'}(q+1)=k'\frac{1}{l_2\sqrt{3}}((\rho_{i,j,1}(q)-\rho_{i,j,2}(q))-(\rho_{i,j-1,1}(q)-\rho_{i,j-1,2}(q))),$$

where $\rho_{i,j,s}$ is the displacement along the normal of the s-th reference point of the i,j-th module, the system equations are put into the form of Equation 34 and with $|k'| < 1$ the asymptotic stability for the regulation procedure is guaranteed. We can thus take it for granted that a structure will possess asymptotic stability if it differs only slightly from the ideal through inaccuracies in manufacture and strain.

Conclusion

The following results have been obtained in this work.

1. The feasibility was shown for building an extendable, maneuverable modular structure so that the shape of the RF-reflective surface can be regulated without elastic strain in the elements.

2. An iterative process is proposed for driving the reference points to the stabilization surface.

3. A class of control laws is shown that provide local stability for the reference points of modules for a structure with a sufficiently long focal length.

BIBLIOGRAPHY

1. Buyakas, V. I.; Gvamicheva, A. S.; Gorshkov, L. A.; et al. KOSMICHESKIYE ISSLEDOVANIYA, Vol 16, Nos 5, 6, 1978.

2. Snitko, I. K. "Stroitel'nyye konstruktsii" [Structural designs], Moscow, Vysshaya shkola, 1966.

3. Sternberg, S. "Lektsii po differentsial'noy geometrii" [Lectures on differential geometry], Moscow, Mir, 1970.

4. Uitteker, E. T. "Analiticheskay dinamika" [Analytical dynamics], ONTI [Association of Scientific and Technical Publishing Houses], 1937.

5. Bromberg, P. V. "Matrichnyye metody v teorii releynogo i impul'snogo regulirovaniya" [Matrix methods in the theory of bang-bang and pulse control], Moscow, Nauka, 1967.

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'AIR & COSMOS' COMMENTARY ON FUTURE SOVIET SPACE PROJECTS

Paris AIR ET COSMOS in French No 780, 27 Sep 79 pp 38-39

[Article by Albert Ducrocq: "The Major Soviet Projects"]

[Text] This morning the Soviets celebrated the second anniversary of Salyut-6. A Proton rocket, launched at Baykonur at 0700, placed the station in orbit on 29 September 1977.

We must stress the engineering success represented by keeping Salyut-6 in a condition of habitability for 2 years. The success is all the more remarkable since in the beginning the operation looked rather in bad shape with the error of Soyuz-25 which led to fears of a deterioration of the station's forward docking port. If that had been the case, the Russians would have had to be content with using Salyut-6 in the manner of their earlier stations, in other words, like a Salyut with a single docking unit. It would have been impossible for them to carry out the program which permitted intensive exploitation of the station, essentially because the 13 tons of payload which, over a period of 2 years, were brought into Salyut-6 by Progress vehicles docked to the aft section of the station while the Soyuz maintenance crew was moored to the forward section.

Thanks to this configuration, the Soviets were able to resupply their station with fuel and at the same time send up equipment to replace that considered essential. As far as secondary equipment units, the Soviets were content with following their evolution, noting with satisfaction that some of those units performed rather well: the on-board clock, guaranteed for 100 days, was still working perfectly six times as long.

This, as we know, was one of the objectives: in preparation for their future permanent station, the Russians wanted to gather the necessary data in order to perfect "lasting" instruments. And from that viewpoint, Salyut-6 was supposed to have been a test platform of inestimable value. One may speak of a jump in equipment longevity which is at least as important as the one recorded in the duration of the flight, which itself created quite a sensation.

From this viewpoint, Soviet doctors have every reason to be satisfied. Lyakhov and Ryumin underwent their first examination at the very place where they arrived, 30 minutes after landing. The Soviet doctors found the cosmonauts to be euphoric in rather awkwardly assuming the vertical position although one of them (Lyakhov), experienced vestibular problems. But the recovery of these two men was much faster than anticipated thanks to the recovery complex. Just 3 days after their return, they had cleared the critical threshold of readjustment to earth conditions. Two weeks spent at Baykonur--with light calisthenics, massages, rehabilitation, and time in the swimming pool--sufficed to enable the two men to resume their normal activities. This is most extraordinary if we remember the very reserved predictions which were made 2 years ago regarding space flight projects whose duration exceeded 3 months.

Salyut-6 Still Available

All problems are far from resolved but it is true that man is at once the transcendent medicine and the most delicate machine there is. We may, however, say that the specialists are now on the path that should lead to still longer flights, even if we persist in our judgment made at the beginning of the year that in order to take a significant step forward, there would have to be a new Salyut model, considerably improved in technical and medical terms. This apparently is one of the major tasks that the Russians have to accomplish before the completion of their Salyut program; using basically the same structure, they have to design a new inhabitable module in the light of the lessons learned over the past several years.

In any case, the exploitation of Salyut-6 should under no circumstances be considered terminated today. The station has its two docking units free to receive, as in the past, a Soyuz at one and a Progress at the other; there is no reason to think that these units should not be reused by crews that might come to inspect the station in order to get a precise idea of the aging of its systems. We would not be astonished by a new and very long mission rather soon--this time with visits by crews which would include a Hungarian and then a Cuban--on board this old but solid Salyut-6 station, whose future technically seems to be more important than its past. Its current altitude assures it of a lifetime of several years and it is certain that, precisely in order to observe the performance of their equipment, the Soviets would leave it in orbit as long as they can.

Persuaded that, within the framework of the manned flight program, Salyut-6 will be further utilized, observers thus believe today that it may perhaps be necessary to postpone the operation of Salyut-7 for a rather long time. It has at any rate been hinted that the differences between Salyut -7 and Salyut-6 will be quite considerable because Salyut-6 has furnished an enormous volume of data which the Soviets will not fail to take into account as well as because the time passing between Salyut-6 and Salyut-7 will have been longer than the entire Salyut program.

Shatalov and the Moon

The Russians today may well visualize vast projects beyond these Salyut missions and they are not going to fail to follow through.

Thus Vladimir Shatalov made a somewhat resonding statement a week ago in Geneva during a luncheon given by the ITU to which he had been invited as the guest of honor. The cosmonaut--who is currently director of training programs in Star City--confirmed that henceforth "the neutralization of the consequences of a long state of weightlessnesss does not constitute an insurmountable problem." The Soviets, as we know, think that the key to success in the 175-day flight were the gymnastic exercises of Lyakhov and Ryumin since these two men worked in the mini-gymnasium for a longer time than their predecessors and made greater efforts, if only because of the stronger springs which had been attached to their sweatsuits. According to Shatalov, the combined action of physical exercise and electrical stimulation can keep the muscles in good condition.

Moreover, Shatalov declared that he was "convinced that the duration of space flights could be prolonged" but the cosmonaut hinted at flights to the moon and Mars in a perhaps not too distant future.

It has indeed been a long time since the Soviets have talked about the moon. And we have always been sure that they were thinking about it a lot in their own way, that is to say, from the perspective of setting up scientific stations on our natural satellite where crews could remain for a long time.

Missions of this nature undoubtedly could coincide with interplanetary flights, flights which to a certain extent would be easier than the lunar missions if one simply required the crews to travel without landing on another planet.

Kamenskiy and Venus

Shatalov talked to us about Soviet flights to the moon and Mars. Shortly before that, another possibility was mentioned by Mr Heinz Kamenskiy.

The latter announced to us last year that the Russians could send a couple into orbit in order to procreate the first baby in space. The director of the Bochum Observatory today believes that, by virtue of its duration, the performance of Lyakhov and Ryumin directly prepared for a mission to Venus.

One can certainly imagine a flight from earth to Venus and back (with a passage at a distance between 400 and 4,000 kilometers from Venus), lasting about 7 months--leaving earth about 2 months before an inferior conjunction of Venus and resorting to a judicious gravity reaction during the over flight of the neighboring planet. Such a manned planetary mission would present the advantage of being extremely spectacular, due to the fact that it would permit men to travel some 100 million kilometers away to observe a planet;

at the same time it would be scientifically interesting because a research program could obviously be carried out during the Venus by-pass.

We agree with this line of thinking: the Russians are undeniably preparing manned planetary missions, the flight from earth to Venus and back as well as the flight from earth to Mars and back. These missions will be conducted as soon as they are materially possible. That, of course, will not be tomorrow. In spite of the extraordinary success of Salyut-6 we must note that during the decade now ending, the Soviet orbital station program has fallen behind schedule: the accident reported in 1971 during the return of Dobrovol'skiy, Patsayev, and Volkov, the need for reconsidering the entire Salyut program from the viewpoint of occupying the stations by only two men, the erratic maneuvers of Soyuz ships, the various difficulties encountered in the perfection of equipment--all these resulted in the postponement by several years of projects whose rapid implementation one could still visualize in 1971.

On the contrary, you might say, everything now seems to be going well for the Russians, This is proven by the way in which they were able to cope last April with the situation caused by the failure of Soyuz 33.

Of course. But the fact remains that manned planetary missions cannot be launched on short notice. They appear unthinkable to us over the next several years even though certain specialists are announcing them.

We must keep the following in mind:

1) Lyakhov and Ryumin were able to remain in space for 175 days (and, as we said before, we can very easily conceive of a situation in which the 200-day limit might be exceeded by their successors). But throughout their entire mission, the cosmonauts had the benefit of permanent support from the ground with the arrival of four automatic vehicles, three Progress vehicles and one Soyuz. This kind of support will be absolutely inconceivable for a planetary mission. There will not be any question of sending a support vehicle because the laws of mechanics absolutely prohibit this. In other words, it will be necessary to be sure that from the very beginning the mission carries everything necessary for the entire duration of flight; this raises a problem of tonnage and a problem of mission design to the extent that the vehicle will have to have very long-life equipment and will also have to be equipped to cope with the unexpected.

2) Although economical, an earth-Venus-earth flight will require the speed of Salyut to be increased from 7.8 to approximately 12 kilometers per second and the creation of a supplementary impulse of 4 kilometers per second will require a volume of fuel representing more than double the mass in flight.

We might add that a planetary flight with only two men would be difficult to conceive. A crew of between four and twelve cosmonauts could constitute a much more respectable base not only in terms of maintenance operations but also to make sure that the mission will have real scientific significance.

The Modular Phase

Let us, therefore, not go from one extreme to the other. As far as we know, operations of the modular type in Russian cosmonautics will commence in 1983. The Soviets will try to dock two and then three modules of the Salyut type, and there is nothing to prevent one of these modules from being an engine block with its own fuel reserve. The important thing is to perfect the entire technique that will permit the construction of huge stations assembled section by section, and we can very well conceive that this program represents the test bed which will make it possible to perfect the engineering for the vehicles which themselves will be modular and which will be designed to travel very far away from the earth.

Judging by the time that was necessary to develop the Salyut itself, this modular program could last, depending upon events, between 5 and 10 years; in other words, we might expect around 1990 a major trip away from the earth by crews occupying huge modular vehicles.

In any case, it is probable that the first long-distance flight for a vehicle of this type will be in a solar orbit very close to that of the earth. To attain such an orbit, it would in effect suffice to achieve a velocity barely faster than the escape velocity such that, on this solar orbit, the period of revolution around the sun would be 1 year. Thus, after 1 year, the station would automatically come back to a position close to earth.

The moment all of the problems involved in permitting a crew to live in space for 1 year without receiving resupply from earth have been solved, it will no longer be difficult (it will simply suffice to have power plants generating 3.2 km/s) to send this crew around the sun on an annual orbit rather than leaving it as an earth satellite, which would cause the vehicle to travel several millions of kilometers away. And that already represents a sensational exploit with the advantage of possible assistance throughout the mission; it has been shown that in case of emergency, in contrast to the rendezvous orbit with the planet, an annual orbit would permit these connections with earth at intervals that are not too long and at acceptable costs.

Events, therefore, could move very fast. These developments--the grand conquest of space--should apparently be expected during the last decade of the century.

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FUNDAMENTALS OF DESIGNING SPACE SEXTANTS

Moscow OSNOVY PROYEKTIROVANIYA KOSMICHESKIKH SEKSTANTOV (Fundamentals of Designing Space Sextants) in Russian 1978 signed to press 7 Sep 78 pp 4, 215-216

[Annotation and table of contents from book by A.G. Nikolayev, I.A. Zabelina, N.F. Romanteyev and V.P. Rudakov, Izdatel'stvo "Mashinostroyeniye," 216 pages]

[Text] Annotation. This book is one of the first publications in the Soviet literature which gives a comprehensive exposition of the problems involved in designing visual space sextants for the autonomous navigation of manned spaceships. The authors examine the physical principles and requirements lying at the basis of the design of astro-measuring devices for space navigation, methods for selecting the optical, photometric and accuracy characteristics, the problems involved in their further improvement, and ways to increase the effectiveness of the use of sextants in manned space vehicles. The book is based on the results of research and the experience of the joint work of the authors in the design and use of space sextants. The book is intended for engineers and designers specializing in the field of instrument making for space purposes and it can be useful to students at higher schools.

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JET SYSTEMS FOR CONTROL OF SPACE VEHICLES

Moscow REAKTIVNYYE SISTEMY UPRAVLENIYA KOSMICHESKIKH LETATEL'NYKH APPARATOV (Jet Systems for Control of Space Vehicles) in Russian 1979 pp 2, 230-231

[Annotation and table of contents from book by N. M. Belyayev, N. P. Belik and Ye. I. Uvarov, Izdatel'stvo "Mashinostroyeniye," 232 pages]

[Text] Annotation. The book sets forth the problems involved in the theory of designing jet systems for controlling spacecraft. The authors examine the schematic diagrams and design features of jet systems, the field of their application as well as elements of the automation system. The book is intended for engineering and technical workers engaged in the development of rocket and space technology.

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SPACE RADIO COMMUNICATIONS

Moscow KOSMICHESKAYA RADIOSVYAZ' (Space Radio Communications) in Russian 1979 signed to press 18 Dec 78 pp 2, 278-279

[Annotation and table of contents from book by N.T. Petrovich, Ye. F. Kamnev and M. V. Kablukova (second edition, revised and supplemented), Izdatel'stvo "Sovetskoye Radio," 5,000 copies, 280 pages]

[Text] Annotation. The authors examine the principal problems involved in constructing systems for surface radio communication using relay apparatus on an artificial earth satellite and employing relay apparatus on the moon. A number of methods for modulation on space radio links are analyzed; and the noise immunity of space radio links is evaluated, taking into account the statistical character of the parameters determining their energy characteristics. Also presented are the principal peculiarities of communication between the earth and a spacecraft. The book examines the possibilities of communication with other planets. The optimum parameters of the communication system were determined for all the cases considered. The book is intended for engineers working in the field of space radio communications, instructors and students. Figures 107, tables 37 and bibliography of 121 items.

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LANDING SPACE VEHICLES ON THE PLANETS

Moscow POSADKA KOSMICHESKIKH APPARATOV NA PLANETY (Landing Space Vehicles on the Planets) in Russian 1978 signed to press 16 May 78 pp 2-4, 159

[Annotation, foreword and table of contents from book by V.I. Bazhenov and M.I. Osin, Izdatel'stvo "Mashinostroyeniye," 2,500 copies, 159 pages]

[Text] Annotation. This book examines the problems encountered by the developers of landing and descent space modules in an investigation of their design and flight performance. The authors set forth the methods for parametric computations for descent modules of different types; the problem of ascertaining their optimum parameters is formulated; and physical modeling methods are described. In accuracy of the results and required time input, the analytical methods for investigating the dynamics of a soft landing set forth in the book, are entirely acceptable for practical engineering computations. The book can be useful to the designers of space vehicles, to scientific workers engaged in investigation of the problems involved in descent and landing, and also to graduate students and undergraduates at colleges in the corresponding fields of specialization.

Foreword. This book acquaints the reader with the problems involved in the descent and landing of space vehicles on planets. The successes of space technology in this direction are obvious: vehicles created by human hands are landing on the moon, Venus and Mars, and are successfully returning to the earth from orbits and interplanetary trajectories.

Soviet and foreign publications have now described methods for computing trajectories, gas dynamics and heat exchange during the flight of a spacecraft in the atmosphere. As a rule these books contain methods and algorithms requiring time-consuming numerical computation procedures for determining only some parameters of space vehicles. Unfortunately, it is impossible to formalize rigorously all the operations in the process of designing space vehicles. In actual practice it is necessary to seek analogues and common characteristics in the design of new space vehicles; to use methods of approximate parametric design evaluations on the basis of simplified computation models; and to draw upon the results of experiments, applying the methods of the theory of similitude and analysis of dimensionalities for determining the configuration of space vehicles operating under new and unusual conditions.

It is obvious that within the limits of one book it is impossible to cover the entire diversity of problems related to landing on planets and returning to earth. Even a concise enumeration of these problems with a description and formulation of the principal problems to be solved in the design and laboratory testing of different types of landing modules would require a monograph of several volumes. Accordingly, the authors of this book have limited themselves to an examination of the principal problems related to designing promising descent and landing modules and discussion of the problems which must be dealt with in the immediate future.

In the first part of the book, which is devoted to the problems involved in descent in the atmospheres of different planets, we have given the results of solving design-testing problems associated with determining the configuration and flight performance of descent modules. In particular, for the conditions of descent to the earth we have based flight performance on the acceleration criteria for manned space vehicles entering the earth's atmosphere at a hyperbolic velocity, and approximate mathematical models are proposed for computing the trajectories of controlled descent. For the conditions of descent to Mars, parametric computations have been used for ascertaining the optimum load on the lifting surface; for Venus, rational descent trajectories are determined from the conditions of entry to the subsequent descent into the denser layers of the atmosphere; for Jupiter, modern concepts have been formulated for methods of designing the characteristics of a planetary probe descent module.

The problems involved in the contact of space vehicles with planetary surfaces and the problems in the design of the landing apparatus associated with them can, to a certain degree, be isolated and considered independently of the problems involved in flight in the atmosphere and in the pre-landing deceleration segment. The second part of the book is devoted to the set of problems arising in the process of creating landing modules: from the theoretical methods for computing the dynamics of a soft landing, methods for modeling and planning fundamental kinematics, means for absorbing energy and increasing the stability of landing systems to experimental confirmation of the theoretical results using full-scale models and dynamically similar models.

In the second part of the book we establish the procedures for the physical modeling of a softlanding under terrestrial conditions and obtain and analyze the conditions of similitude necessary for reproducing landing sequences on the moon and other planets during the earth-based testing of space landing vehicles.

The book can be useful to specialists engaged in the design and testing of the landing modules of lunar, Venusian, Martian and other descent vehicles, to individuals engaged in the investigation of the particular problems in the mechanics of landing and the thermodynamics of descent, as well as to students in the corresponding fields of specialization.

The authors express appreciation to Candidates of Technical Sciences A.F. Yevich and R.P. Belonogov for useful advice and comments which they made during examination of the manuscript and to engineers A.I. Goncharov, A.I. Burtsev, Yu. V. Zakharov and V.F. Malykhin for assistance in preparing the manuscript materials for publication.

The authors will receive all comments from readers of the book with appreciation.

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IV. SPACE APPLICATIONS

ANALYSIS OF SPACE PHOTOGRAPHS FOR TECTONO-MAGMATIC AND METALLOGENIC STUDIES

Moscow ANALIZ KOSMICHESKIKH SNIMKOV PRI TEKTONO-MAGMATICHESKIKH I METALLO-GENICHESKIKH ISSLEDOVANIYAKH (Analysis of Space Photographs for Tectono-magmatic and Metallogenic Studies) in Russian 1979 signed to press 2 Mar 79 pp 2, 163-164

[Annotation and table of contents from book edited by I. N. Tomson, Nauka, 1400 copies, 164 pages]

[Text] This work is devoted to the employment of space photographs for the detection of specific structures identifying the site of major deposits within a mining province. The structures of regional significance include extensive dislocation systems reaching the width of the first dozen or so kilometers, not infrequently manifested on the surface in indistinct form. Large deposits within their boundaries are related to the centers of greatest tectonic activity.

The characteristics of structure manifestation on space and high-altitude photographs are reviewed using a number of regions as examples, and special methods of studying them are proposed. Specific means for the local prognosis of ore deposits are discussed.

The book includes 56 illustrations and 148 bibliographic references.

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